Differences between Canadian and Lebanese Pre-service Elementary Teachers on Their Conception of How Children Learn Mathematics

Ramzi Nasser, Notre Dame University, Lebanon

Abstract

This study explores four-year elementary education students' understanding of how children learn mathematics through the use of concept maps. Thirteen Canadian and 9 students from Lebanon participated in the study. Over a two-week period students were asked to reflect on how children learn mathematics. The Lebanese students were prone to produce conceptual structures that were more teacher-centered and curriculum oriented while their Canadians counterparts formed concept maps that were student-centered and cognitive based. Recommendations suggest that larger samples are studied in order to provide a better understanding of socio-cognitive reflections of how future teachers think teaching mathematics.

INTRODUCTION

Concept maps are used to assess the organization of learning, to tap into the cognitive structure and understand specific educational concepts in the subject matter (Novak, 1984). The use of concept maps for the assessment of students' cognitive structures has been relatively unexplored in mathematics education. Particularly, concept maps have been limited in their use to assess how pre-service elementary education students perceive the way schoolchildren learn mathematics.

A concept map is a visual representation of one's own knowledge. It can take the form of a drawing or a diagram that represent a connection between content knowledge and prior knowledge. Concept maps are pictographs linked by arrows and words, which provide information on relationships connecting issues or concepts (Novak, 1990); they have been functional in viewing the development or change in conceptual structures (Songer & Mintzes, 1994; Trowbridge & Wandersee, 1994), assessment of content, and knowledge/diagnostic assessment (Ruiz-Primo & Shavelson, 1996; McClure, Sonak, & Suen, 1999) and as an instructional tool (Barenholz & Tamir, 1992; Elhelou, 1997). Concept mapping appears to fit in well with situations where pedagogical aspects are being uncovered with content (Von Minden, Walls & Nardi, 1998).

The Use of Concept Maps Cross-Nationally

Cross-cultural research into the use of concept maps have been exclusively limited to within-country samples and little work has been done to compare pedagogical and theoretical knowledge of mathematics teaching between cross-national samples. In addition, while aptitude and ability tests have been used to measure domain specific differences between mathematics university students, little work on process skills has sought to cross-examine pedagogical differences and similarities between pre-service elementary education students from two distinct cultural backgrounds. This study compares pre-service elementary college students drawn from two cultures on their understanding of how children learn mathematics. The broad aim is to assess the structural knowledge and pedagogical similarities and differences between Lebanese and Canadian students. In fact, cross-national differences offer an understanding of the transfer of knowledge from one culture to another. Whether pedagogical differences are apparent or not lead us to judge the quality and effectiveness of teacher training programs with the assumption that a skilled teacher who understands how students learn mathematics is a prerequisite to effective teaching (Schroeder & Lester, 1989). In addition, registering cross-cultural beliefs and the way they differ, at the level of epistemology, helps schoolteachers to understand how a teacher in the West defines knowledge of children's learning of mathematics and how teaching mathematics in Western countries converges or diverges with knowledge in collectivist cultures such as Lebanon. This cross-cultural endeavor underscores the cultural parity in mathematics education and sheds light on the understanding of cross-cultural differences in the teaching of mathematics.

It is suggested that teachers' beliefs about mathematics and how children learn mathematics are a product of social interaction that arise from expectations and

interpretations (Bauersfeld, 1988; Cooney, Shealy, & Arvold, 1998). Beliefs, being a product of socio-cognitive processes, where individuals in a community interact, communicate and make decisions, explain specific experience in the teaching and learning of mathematics. By way of reflection, a cultural unique component as knowledge, socially negotiated tasks gives specific rise to epistemologies and contextual elements of cultural behaviors. In the analysis of a task, a teacher makes a re-presentation to determine appropriate strategy where he/she thinks is appropriate for the task (Cooney, Shealy, & Arvold, 1998). This reflection of pedagogical as well as of content understanding of mathematics is in context of experience and training that accents key educational issues in situated action.

Recent mathematics education research (e.g., Barenholz & Tamir, 1992; Elhelou, 1997) has shown that content and styles of pedagogy as a model of pedagogical reasoning and action intersect. In concert with this finding, the present study provides insights into teacher's pedagogical knowledge as representation, selection and adaptation to children's learning characteristics. This research will lend itself to a cross-cultural perspective of mathematics education from the actors within a national context in the hope for educators (university) and policymakers to provide better planning and pedagogical practices. Our hopes are that a universal mathematics education supports the individual as a critical and reflective thinker, actively constructing mathematics by juggling, and relating to previous and new ideas as a way to build up meanings to understanding (Brown, Collins, & Duguid, 1989; Piaget, 1954). Since research on teacher's knowledge helps in the discovery of the nature of pedagogical practices and how they influence instructional decisions, the assessment of pre-service education students knowledge of mathematics is related to the organization of knowledge to teaching; hence the way pre-service education students perceive how teaching and learning of mathematics interact with subject matter knowledge (Fennema & Franke, 1992; Carpenter, 1992; Shulman, 1986).

Validity Issue

Several important issues relating to the use of concept mapping in teaching and in research have emerged in recent years. In comparing pedagogical skills, substantial thinking into the research procedure through observation or through qualitative methods of measuring behavior is appropriate. In some cases, the observations or interview protocols become influenced by a variety of factors related to what is intended and which factors render the instance not clearly specified or intended. While assessments based on concept maps have the desired end to bring out the quality measure in its objective form--it renders the opportunity of mathematics educators to be reflective, schematic, and open to change.

The concept maps are respondent dependent because of the quality of presentation the maps have. Often concept maps become so cumbersome in assessing students' specific knowledge, especially where other components or thoughts are integrated into the map. Targeting one aspect of a concept can often lead to other congruent and related concepts underlining the ambiguity of concept maps. Recognizing these advantages and

disadvantages of concept maps does not solve the problem of validity, which measures the fact that what was supposed to be measured, was really measured by it.

Concept maps are idiosyncratic and depend on the individual's knowledge; hence not truly objective. In concept maps, responses touch on certain aspects at a specific level which makes the whole process of scoring maps difficult to undertake. Questioning the objective validity of concept maps defeats the whole purpose of the exercise; key is the appropriateness in the scoring procedures. These considerations in the assessment are similar to those with extended response exercises, thus considering the open-endedness of both task validity is exercised by the judges of those tasks and scoring schemes they use.

However, there is an advantage to concept maps in that a complete mapping of students' knowledge on a specific concept is achieved by way of a response structure. Unlike extended responses or authentic assessment exercises, these artifacts often elude the true assessment of the task at play. The skill needed in the production of concept maps is minimal compared to the production of essays or authentic tasks as projects, papers and reports. Hence, assessing students' knowledge on a specific task through the concept maps produces the purest form of knowledge that can be represented in quasi-objective manner. However, validity of scoring is palpable as a function of rater expertise and scoring method. According to Kinchin and Hay (2000) "the aggregation of scoring elements creates a blurring [view] of what the overall score actually reveals," (p.46). In some cases where component links are judged irrelevant, they have a greater support to other links of concept maps and judged important to the overall conceptualization of the structure. Validity in scoring is difficult to achieve in evaluating concept maps, and hence, a schema that concurrently supports the qualitative process measures through qualitative procedures accumulates knowledge of task through different types of methodologies.

Scoring the Concept Maps

A number of studies have devised methods to score concepts maps. The scoring schemes have been quantitative and structural in nature. Most notably is Novak and Gowin's (1984) scoring method, which considers higher levels of structure within the concept maps. Score points are accumulated based on the number of propositions, level of hierarchies, and cross-links identified in the maps. According to McClure et.al. (1999), hierarchies show evidence of ordinate, subordinate concepts and connections that define the relations between concepts is evidence of cross-links. The relational scoring method developed by McClure and Bell (1990) is based on the number of propositions evident in the maps. The proposition is made up of two concepts that are linked by an arrow. In addition, the proposition is judged as being correct or incorrect on a rating scale. The more widely used scoring scheme that is susceptible to error and biases is the holistic approach. This approach employs an expert, who judges the map for its quality and ensures whether the response provides evidence for it. While these three methods are more likely to judge the appropriateness of the responses for restricted response type of questions, the scores are measures of quality. If to use any of the scoring schemes to

compare pre-service students' concept maps more specifically their reflection-of-action in the learning of mathematics, a score would reflect a summative and quantitative measure and suggest that a more informative and qualitative assessment of concept maps is required.

Kinchin and Hay (2000) provided a relevant understanding and analysis of the concept maps as an assessment tool, which differentiates maps in terms of hierarchy, processes, complexity, conceptual development, and representation. The analysis is crossed with a generalized conceptual framework of the concept maps made of three forms of map structures that define the map's quality, being the spoke, chain and net (see figure 1). The spoke has a radial structure in which concepts are linked to a main concept but not directly to each other. The chain is a linear decomposition in which concepts are linked to its predecessor in a sequence; this type of structure has little room for additions given that the structure has already been formulated. The net structure reveals a complex web of relations and a schema of modifiable structure that provide evidence to the flexibility of the service-teacher and ability to change conceptions, integrate new concepts and understanding. The net structure also accommodates for hierarchies that are interdependent and linked to a more complex structure. The conceptual framework represented is crossed with map structure which Kinchin et. al. (2000) have perceived in five classifications. These being: hierarchy, process, complexity, conceptual development, and representation. Hierarchy can be either multileveled or single leveled in a net structure; the levels are not an indication of depth but more of latitude to judge the decomposition styles of pre-service students. Processes can be defined by the association between different propositions; in certain instances processes can be sequential i.e., temporal in other complex interactions while complexity deals with integrity in the case were concept map could be very hard to maintain. Finally, representation reflects the curriculum, concept, or lesson at play (Kinchin & Hay, 2000) (See Table 1).

In order to evaluate the concept maps, Kinchin and Hay's qualitative schema was used. It was concurrently validated by a quantitative scoring scheme conceptualized by Novak and Gowin (1984) for which points were given based on the number of propositions, hierarchical levels, and cross-links identified on the maps. In figure 2, for instance, there are 8 propositions, 3 hierarchies and two links. The proposed scoring procedure employed a number of raters who scored the maps to establish support and concurrent validity to the qualitative scoring scheme.

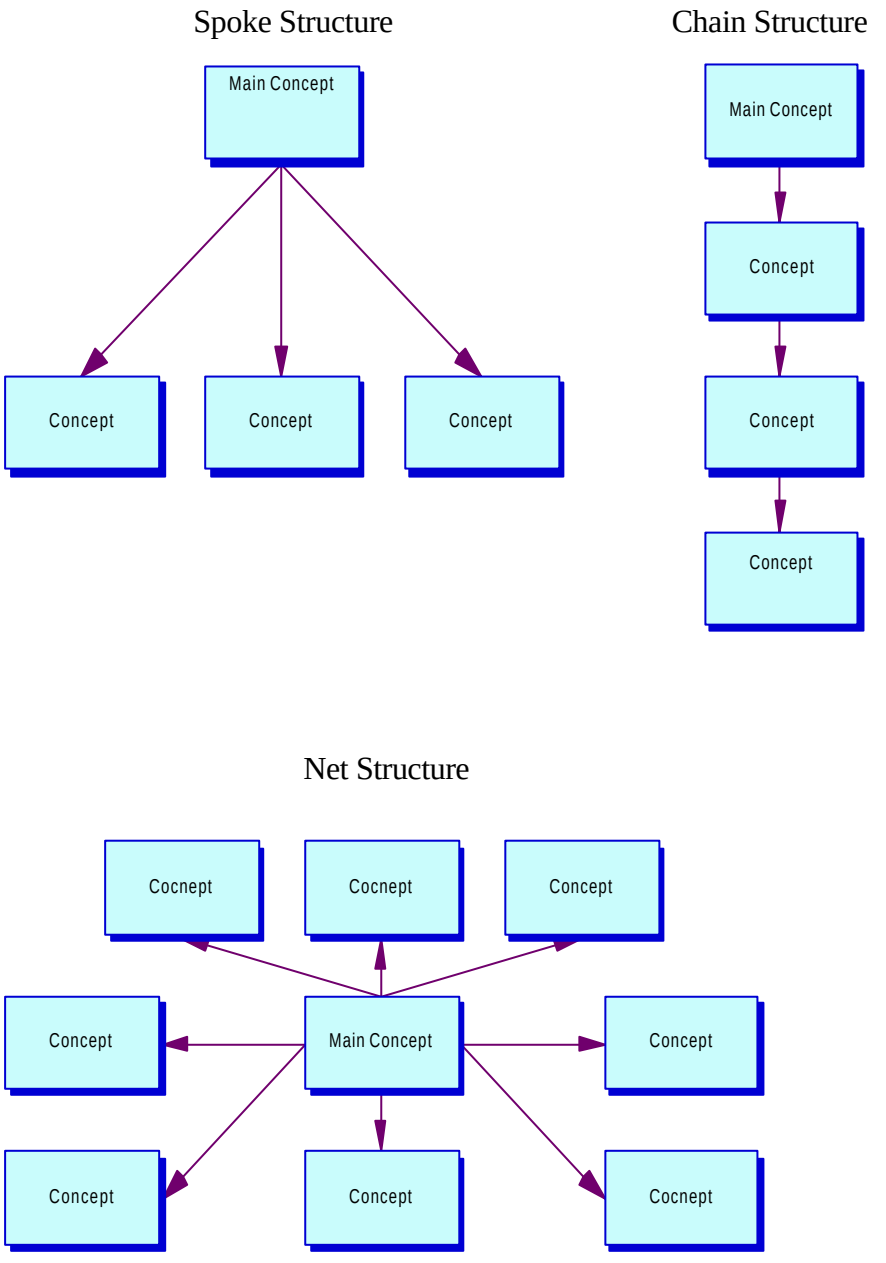

Figure 1
The Three Structure Type of Concept Maps

Table 1

The Three Structures of Concepts Maps Used in the Qualitative Analysis

	Spoke	Chain	Net
Hierarchy	One level only	Many levels, but often incorrect	Several justifiable levels
Processes	Simple association with no understanding of processes or interactions	Shown as a temporal sequence with no complex interactions or feedback	Described as complex interactions at different conceptual levels
Complexity	So little integration that concepts can be added without consequences for 'map integrity'	Map integrity cannot cope with additions, particularly near the beginning of the sequence	Map integrity is high adding one or more concepts has minor consequences as 'other routes' through the map are available
Conceptual development	Shows little or no 'world view'. Addition or loss of a link has little effect on the overview	Integrated into a narrow 'world view', suggesting an isolated conceptual understanding. Loss of a link can lose meaning of the whole chain	Can support reorganization to emphasize different components to appreciate a larger world view or to compensate for a 'missing' link
Represents	National Curriculum structure	Lesson sequence	Meaningful learning

From "How a qualitative approach to concept map analysis can be used to aid learning by illustrating patterns of conceptual development," by I. Kinchin, and D. Hay, 2000, Educational Research, 42(1), p. 48.

METHODOLOGY

A sample of pre-service Canadian (n=13) and Lebanese (n=9) students who were taking senior courses in mathematics teaching methods were purposefully selected for the study. These students were asked to participate to construct a concept map and were taught to practice in the construction of concept maps. Students in Canada were asked to explore the use of Inspiration Software to construct a concept while Lebanese students inscribed their concept maps by hand. The maps were then entered into the Inspiration Software by the principal investigator of the present study.

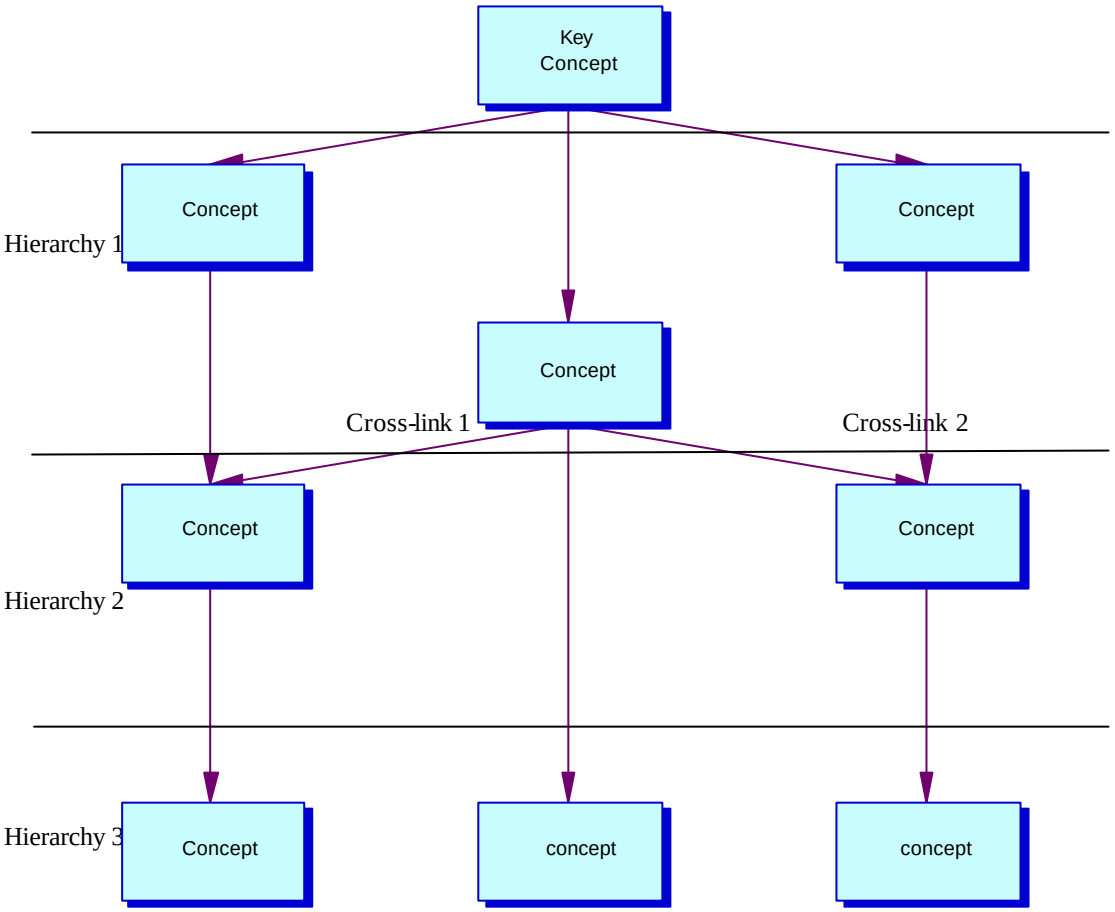

Figure 1
The quantitative schema representing propositions hierarchies and cross-links for scoring concept maps

The Inspiration Software is unique in that it enables learners to reflect on their thinking and accommodate for new learning. Pre-service students in both countries were asked to construct concept maps following a two-step procedure. The first step asked students to brainstorm about how children learn mathematics without referring to scholarly literature or academic material. The second step asked preservice teachers to construct and update their concept maps on a computerized program called Inspiration. Lebanese students, they were asked to edit their work through paper and pencil. This program was easy to use and it allowed the user to continuously review and reflect on his/her thinking process.

Canadian and Lebanese pre-service elementary education students were given two weeks to complete the task. One of the authors trained education elementary students to construct concept maps. These students were requested to form ordinate-subordinate concepts, hierarchies and links or relations between these concepts. Maps were then analyzed based on Kinshin's et. al. schema. The maps were scored based on Novak and

Gowin's (1984) model to provide concurrent validity. Novak's and Gowin's model was used to award points to the number of propositions, hierarchical levels, and cross-links.

ANALYSIS AND DISCUSSION

The maps were analyzed based on the three types of structures, the spoke, net, and structure as modeled by Kinchin, et. al. Two anonymous raters were requested to read the Kinchin et. al., qualitative scheme and were trained by the principal investigator to judge the type of map structure i.e., spoke, chain, or net. Two other raters were asked to judge the rating based on Novak's et. al. scheme. These two anonymous raters were given instruction to tally the number propositions, hierarchies, and cross-links. They were then asked to score each map for the number of propositions, number of hierarchies and cross-links. Two concept maps were piloted between the two raters to determine inter-rater agreement. There was a 100% agreement on hierarchies, however, one rater on a 17-proposition map suggested that there were 15 and a second 16. The raters were asked to consider the maps again and were further probed to the missed proposition. Both raters were able to give an indication to the appropriate number of propositions.

An aggregate score was obtained for the Lebanese and Canadian participants for each of the propositions, hierarchies, and cross-links. The total score for each of the propositions, hierarchies, and cross-links for all the maps was added then divided by the number of maps to obtain a mean score. Table 2 reports the scores for the Lebanese and Canadian samples. A significant difference was found on the number of propositions; Canadians reported a mean of 20 for the propositions more than their Lebanese counterparts (M=14.8). Consistently, the Canadian sample had a higher mean count on the hierarchies and cross-links than the Lebanese sample, but not a significant value. The next section provides the analysis using each of the three structures considering mainly complexity, conceptual development and representation of Kinchin's (2000) qualitative analysis of concept maps

Table 2

Mean Scores and t-test Between Canadian and Lebanese Students based on total score of Propositions, Hierarchies and Cross-links

	Propositions			Hierarchies			Cross-links		
	Mean	SD	N	Mean	SD	N	Mean	SD	N
Canadian	20	3.7	13	3.69	1.5	13	1.1	2.6	13
Lebanese	14.8	4.8	10	3.4	1.4	10	0.3	0.7	10
t-test	2.87**(df=21)			0.49(df=21)			1.02(df=21)		

** p=0.001

Qualitative Analysis

Spoke structure

Three students from the Lebanese sample presented a spoke structure. These maps were simple with little interactions i.e., cross-links and had at least 2 or more hierarchies. None of the maps were looped reflecting a rigid conception of learning. One Lebanese student presented learning in terms of a lesson plan with content severed from its evaluation. Among the three Lebanese pre-service students who presented a spoke structure, none viewed learning from the perspective of learning theory showing little cognitive processes involved in the learning of mathematics. One Lebanese student presented the learning as being linked to scaffolding with one level of hierarchy. The results show little integration in the spoke structures among the three Lebanese students, consequently with little overall integration. The maps indicated a conceptual development having a reflection of a curriculum based on a set of activities, competencies, and objectives barely relevant to learning theories. One map represented the Lebanese curriculum requirements, which consequently provided notes, and helpful hints to teachers who suggested the preponderance of pre-service with organizational issues rather a student-centered learning. Keeping in mind the three spoke concept maps attempted to list some content represented in the Lebanese national curriculum and were mostly incomplete reflections dealing with computation, operations, and geometry.

Three Canadian pre-service students presented a spoke structure out of the 13 concept maps. Two showed 4 hierarchical levels and one showed 7 hierarchical structures. One of the Canadian students presented a cross-link between the processes of questioning as an instructional method with student problem-solving. The second concept map presented decomposition--then—connect structure, which linked super-ordinate concepts to a down the line subordinate concepts by skipping one level of hierarchy. The two concept maps showed little integration in their map structure. Loss of facts or propositions was seen not to have a major effect on the maps. In one map, for instance, the concept of reflective thinking was linked to sharing a finding. In the second map, the concept developing a number sense was connected to play; thus, the two concepts were redundant since they did not have any consequential relation. The Canadian pre-service students differed from those Lebanese as concepts were more related to student learning emphasizing problem-solving, heuristics, recognition of patterns, playing, trial and error, working with manipulative and physical representation. One of the concept maps was alluded to Piaget's constructivist notions of learning and related manipulative use and active engagement in the learning of mathematics and another map corresponded to George Polya's problem-solving schema. In addition, Canadians differed from their Lebanese counterparts by alluding little to the curriculum and content while linking the teaching process to learning theories without disembodying them from practice; hence presenting a continuum between learning and practical teaching.

Net structure

Among the Lebanese and Canadian samples, there was no evidence of the chain structures. The rest of the 10 and 6 maps drawn by the Canadian and Lebanese samples respectively were of the net structure. Two Lebanese students presented two hierarchies, three persons with 3 hierarchies, one person with 4 hierarchies and one person with five hierarchies. On the other hand, the Canadian sample comprised one person with 2 hierarchies, six persons with 3 hierarchies, one person with 4 hierarchies, one person with 5 hierarchies and one person with 6 hierarchies. Comparing the Lebanese and Canadian samples on their mean count of hierarchies for the net structure ($t=0.64$, $df=15$, $p=0.36$), no significant difference appeared between them. In addition, there was little interaction evident in the concept maps among the Lebanese respondents. One individual linked teacher strategies with student strategies of learning mathematics and teacher created objectives with trying to reach as an active learner, objects to the child. Two other pre-service students indicated a constructivist notion of learning but none of them linked constructivism with problem solving. One student created a subordinate concept-- linked to other disciplines and gave an example-- language arts and reading problems. Another student linked constructivism to multiple intelligence and meta-cognition with no further decomposition. Five of the six Lebanese students presented problem solving as a means to children's learning of mathematics. This concept in four of the cases was separated from verifying solution, communicating, analyzing, and looking at examples. Students who mapped constructivist learning did not link it to the super-ordinate concept of problem solving. In two cases problem solving was an end of the line concept i.e., last in the hierarchy. In some other cases it was linked to instructional effectiveness and the curriculum. The Lebanese sample through the net structure indicated learning mathematics through use of mathematics artifacts as graphs, diagrams, tables, manipulative, symbols, and textbooks.

In comparing the two samples, Canadian pre-service students were more prone to produce concept maps that involved cooperative learning, supported learning and modeling. All Canadians exhibited a reflection for the need for cooperative learning, creativity, and individual learning through inquiry. Three of the 10 net-structure concept maps explored reasoning as a way for learning mathematics. One student has presented reasoning at the end of the line, while another provided it as super-ordinate concept, which decomposed into exploring, creating, judging, comparing and analyzing. A third student explored reasoning as a super-ordinate concept to deductive, inductive, and spatial type of reasoning. None of the three students linked reasoning to problem-solving or mathematical artifacts as manipulative or activities. Five of the 10 students explored the concept of problem solving and two others explored problem-solving concepts as super-ordinate concepts with exploration, strategies and thinking processes, and activities as sub-ordinate concepts. That same individual cross-linked problem-solving to creativity and did not further explore this connection. A second student explored problem-solving concept with solving and student constructed solutions as sub-ordinate concepts. The three other students reflected on problem solving as the end of the line conception. One student explored the information processing model with a complex inter-related conceptual framework connecting working memory to long term memory, to elaborate

rehearsal, to semantic knowledge, and attention and chunking. This concept map was purely theoretical and tasks were presented at the cognitive level. In addition, five of the ten net structures also exhibited a quasi-scientific method to the learning of mathematics, as observing, analyzing solving, questioning, and verifying the solution. These concepts were connected in a chain in the net structure.

It is evident that Canadian students had incorporated more information into their final map, with a more hierarchical organization than their Lebanese counterparts. The Lebanese student maps elaborated more on curriculum components, and content background; of who none has sought to integrate or link these maps viz. curriculum with the problem solving. Certainly among the Lebanese sample preponderance with classroom management as control of behavior, conformity to the curriculum, and listening to the teacher was a concern for them. The general organization of the maps reflected those of the textbook (Musser & Burger, 1997) which was used in a semester long program. These students who have mentioned Piaget did not relate their conception to the constructivist notions. Hence, these views remained cornered with no cross-links to other concepts. Lebanese students were more prone to reflect on Polya's notion of problem-solving model, in some cases the model is incomplete and not necessarily completed in the order listed. By contrast, Canadian students' reflections were more student-centered, and reflected more with what children had to act and do in order to learn. It was visible that Canadians alluded to learning theories and learning strategies more than the Lebanese preservice teachers. These reflections were profoundly more pertinent to the child's cognitive processes. The fact that little cross-links and interactions were evident among the two samples provided naïve and simple views of the understanding of how children learn mathematics.

CONCLUSION

The concept maps drawn by Canadian and Lebanese samples provided an insight into how pre-service education students think about how children learn mathematics. Among the Lebanese students, the reflections through the mapping procedure revealed that students have primary concerns with the curriculum and mathematical artifacts for which they perceive children's learning of mathematics. While, Canadian pre-service students reflected some understanding of theoretical framework of learning and exhibited more cognitive to the learning of mathematics than their Lebanese counterparts. Furthermore, Canadian students also demonstrated a high number of propositions. Program focus was also exhibited between the two samples which showed certain ideas such as assessment and program guidelines. Turning to the constructivist perspective which considers learners as constructing meaning by actively working with ideas, relating new ideas to prior knowledge, modifying and generating knowledge through reexamination and reorganization (Rumelhart & Ortony, 1977), the Lebanese preservice teacher constructivist notion conception of constructivism in learning was in tandem with the Lebanese national curriculum. However, Lebanese students showed little ability to substantiate constructivism through the inclusion of schoolchildren as actors rather than observers of constructing knowledge. The constructivist notions of learning being registered by Lebanese and Canadian students reflected a philosophy to elementary

education program. Hence, it is possible to organize teacher education curriculum around concepts highlighted among student maps (Beyerbach & Smith, 1990). Certainly, if constructivism is to permeate the curriculum among Lebanese, more child-centered styles of pedagogy should be integrated into the content of the mathematics curriculum. Therefore, in order to fully acknowledge constructivist notions of learning through mathematics education, educational policymakers and researchers need to reconceptualize school mathematics, particularly in Lebanon. The first thing to do is to view mathematics as a living and developing body of knowledge, not a static *fait accompli* devoid of self-direction. For an effective mathematical teaching program to take hold in Lebanon, math educators should be trained in the en routes of shifting teaching from teacher-centered approaches to student-centered ones allowing for experimentation, self-learning, inquiry and reflection.

REFERENCES

Barenholz, H. & Tamir, P. (1992). A comprehensive use of concept mapping in design instruction and assessment. Research in Science and Technological Education, 10(1), 37-52.

Bauersfeld, H. (1988). Interaction, construction, and knowledge: Alternative perspectives for mathematics education. In D. Grouws, T. Cooney, & D. Jones (Eds.) Perspectives on research on effective mathematics teaching (pp.27-46). Reston, VA: National Council of Teachers of Mathematics.

Beyerbach, B. & Smith, J. (1990). Using a computerized concept-mapping program to assess pre-service teachers' thinking about effective teaching. Journal of Research in Science Teaching. 27(10), 961-971.

Brown, J. S., Collins, A. & Duguid, P. (1989). Situated cognition and the culture of learning. Educational Researcher, 18, 32-42.

Cooney, T., Shealy, B., & Arvold, B. (1998). Conceptualizing Belief structures of pre-service secondary mathematics teachers. Journal for Research in Mathematics Education, 29(3), 306-333.

Elhelou, M. (1997). The use of concept mapping in learning science subjects by Arab students. Educational Research, 39(3), 309-317.

Kinchin, I., Hay, D. (2000). How a qualitative approach to concept map analysis can be used to aid learning by illustrating patterns of conceptual development. Educational Research, 42(1), 43-57.

McClure, J., Sonak, B., & Suen, H. (1999). Concept map assessment of classroom learning: reliability, validity, and logistical practicality. Journal of Research in Science Teaching, 36(4), 475-492.

Muser, G. & Burger, W. (1997). Mathematics for Elementary Teachers: A contemporary Approach. Upper Saddle River, NJ: Prentice Hall.

Von Minden, A., Walls, R., & Nardi, A. (1998). Charting the links between mathematics content and pedagogy concepts: cartographies of cognition. The Journal of Experimental Psychology, 66(4), 339-358.

Piaget, J. (1954). The construction of reality in the child. New York: Ballantine Books.

Ruiz-Primo, M. & Shavelson, R. (1996). Problems and issues in the use of concept maps in science assessment. 33(6), 569-600.

Rumelhart, D. W., & Ortony, A. (1977). The representation of knowledge in memory. In R. C. Anderson, R. J. Spiro, & W. E. Montague (Eds.). Schooling and the acquisition of knowledge (pp.99-136). Hillsdale, N.J: Lawrence Erlbaum Associates.